One of the most important of these, I venture to think, is the extension of co-operative research, both scientific and industrial. In the case of industrial work manufacturers are afraid of making their wants and difficulties known lest the mere statement of them should enable a British rival to find a solution and get ahead. It is necessary to appreciate, however, that rivalry between British manufacturers is not nearly such a serious matter as the competition of Germany with all of them will become, and that British manufacturers will have to stand shoulder to shoulder to meet the common foe. German firms do not hesitate to pool their knowledge if it enables Germany to get ahead of other nations, and British trades will therefore have to meet this organisation by one of a similar kind. In the same manner I have long been convinced that far greater advances might be made in purely scientific research in many departments of knowledge if we were to adopt more extensively the custom of associated work. I mean by this the formation of committees of workers, not too large for expeditious decisions, but charged with the duty of investigating certain formulated problems. It is in this respect that our learned societies might do so much more than they do. The proceedings of these societies are mostly a record of isolated, disconnected pieces of work of very different scientific value. But if properly organised discussion were brought to bear on the question, it would be possible to induce investigators of reputation and ability to associate themselves more in conjoint work to the great advantage of our common knowledge. The learned societies should therefore fulfil to the adult and experienced investigator the same function which the professor or teacher should fulfil to his research students, viz., supply them with suggestions for lines of research to stimulate thought and invention.

It is quite certain that we shall have to organise in this way to a far higher degree than we have yet done what may be called the strategy of research, and that the learned societies should act in some capacity like the great general staff of an army towards the subordinate generals and corps commanders. We require therefore to get on to the councils of our learned and technical societies and into their presidential chairs not merely men eminent for their private researches, but men of large ideas with organising abilities and inspirational power. If we do not do this, then, although by a lavish sacrifice of life and treasure we may win, as we are determined to do, in the military and naval operations, we shall in the long run be hopelessly defeated in that slower but none the less deadly scientific and commercial competition which will follow upon the cessation of actual hostilities.

THE BRITISH ASSOCIATION.

SECTION D.

ZOOLOGY.

Opening Address[1] by Prof. E. A. Minchin, M.A., Hon. Ph.D., F.R.S., President of the Section.

The Evolution of the Cell.

I propose in this address to deal with an aspect of cytology which appears to me not to have received as yet the attention which it deserves, namely, the evolution of the cell and of its complex organisation as revealed by the investigation of cytologists. Up to the present time, the labours of professed cytologists have been directed almost entirely towards the study of the cell in its most perfect form as it occurs in the Metazoa and the higher plants. Many cytologists appear, indeed, to regard the cell, as they know it in the Metazoa and Metaphyta, as the beginning of all things, the primordial unit in the evolution of living beings. For my part I would as soon postulate the special creation of man as believe that the metazoan cell, with its elaborate organisation and its extraordinarily perfected method of nuclear division by karyokinesis, represents the starting-point of the evolution of life. So long, however, as the attention of cytologists is confined to the study of the cells building up the bodies of the higher animals and plants, they are not brought face to face with the stages of evolution of the cell, but are confronted only with the cell as a finished and perfected product of evolution, that is to say, with cells which, although they may show infinite variation in subordinate points of structure and activity, are nevertheless so fundamentally of one type that their plan of structure and mode of reproduction by division can be described in general terms once and for all in the first chapter of a biological text-book or in the opening lecture of a course of elementary biology.

One of the most striking features of the general trend of biological investigation during the last two decades has been the attention paid to the Protista, that vast assemblage of living beings invisible, with few exceptions, to the unassisted human vision, and in some cases minute beyond the range of the most powerful microscopes of to-day. The study of the Protista has yielded results of the utmost importance for general scientific knowledge and theory. The morphological characteristic of the Protista, speaking generally, is that the body of the individual does not attain to a higher degree of organisation than that of the single cell. The exploitation, if I may use the term, of the Protista, though still in its initial stages, has already shown that it is amongst these organisms that we have to seek for the forms which indicate the evolution of the cell, both those lines of descent which lead on to the cell as seen in the Metazoa and Metaphyta, as well as other lines leading in directions altogether divergent from the typical cell of the text-book. We find in the Protista every possible condition of structural differentiation and elaboration, from cells as highly organised as those of Metazoa, or even in some cases much more so, back to types of structure to which the term cell can only be applied by stretching its meaning to the breaking-point.

It is impossible any longer to regard the cell as seen in the Metazoa and as defined in the text-books as the starting-point of organic evolution. It must be recognised that this type of cell has a long history of evolution behind it, which must be traced out, so far as the data permit. The construction of phylogenies and evolutionary series is, of course, purely speculative, since these theories relate to events which have taken place in a remote past, and which can only be inferred dimly and vaguely from such fragments of wreckage as are to be found stranded on the sands of the time in which we live. All attempts, therefore, to trace the evolution of the Protista must be considered as purely tentative at present. If I venture upon any such attempt, it is to be regarded as indicating a firm belief on my part that the evolution of the cell has taken place amongst the Protista, and that its stages can be traced there, rather than as a dogmatic statement that the evolution has taken place in just the manner which seems to me most probable.

Before, however, I can proceed to deal with my main subject, it is absolutely necessary that I should define clearly the sense in which I propose to use certain terms, more especially the words "cell," "nucleus," "chromatin," "protoplasm," and "cytoplasm." Unless I do so, my position is certain to be misunderstood, as, indeed, it has been already by some of my critics.

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[1] Abridged by the author.

The term cell was applied originally to the protoplasmic corpuscles building up the bodies of the Metazoa and Metaphyta, each such corpuscle consisting of a minute individualised mass of the living substance and containing a nucleus. Hence a complete cell is made up of two principal parts or regions, the nucleus and the remainder of the protoplasmic body, termed the cytoplasm. By some authors the term protoplasm is restricted to the cytoplasmic portion of the cell, and protoplasm is then contrasted with nucleus; but it is more convenient to consider the whole cell as composed of protoplasm divided into two regions, nucleus and cytoplasm.

We come now to the consideration of the body termed the nucleus, which undoubtedly possesses an importance in the life and functions of the cell far greater than would be inferred from the name given to it. I have described in general terms the typical nucleus of the text-books, as found commonly in the cells that build up the bodies of ordinary animals and plants. The minutiæ of the details of structure and arrangement of the constituent parts may vary infinitely, but the type remains fairly constant. When we come, however, to the nuclei of the Protista, such pronounced modifications and variations of the type are met with that a description in general terms is no longer possible. I will direct attention now only to one point. In the protist cell the chromatin is not necessarily confined to the nucleus, but may occur also as extranuclear grains and fragments, termed chromidia, scattered through the protoplasmic body; and the chromatin may be found only in the chromidial condition, a definite nucleus being temporarily or permanently absent.

The essential part of the nucleus is the chromatin, and the other structural constituents of the nucleus, namely, membrane, framework, and plastin or nucleolar bodies, are to be regarded as accessory components built up round, or added to, the primary nuclear material, the chromatin. Even with regard to the nuclei of Metazoa it is maintained by Vejdovsky that at each cell-generation the entire nucleus of the daughter-cell is produced from the chromosomes alone of the mother-cell. The simplest body which can be recognised as a nucleus, distinct from the chromidia scattered without order or arrangement throughout the protoplasmic body, is a mass of chromatin or a clump of chromatin-grains supported on a framework and lodged in a special vacuole in the cytoplasm.

This brings me to a point which I wish to emphasise most strongly, namely, that the conception of a true cell-nucleus is essentially a structural conception. A nucleus is not merely an aggregation of chromatin; it is not simply a central core of some chemical substance or material differing in nature from the remainder of the protoplasm. The concepts "nucleus" and "chromatin" differ as do those of "table" and "wood." Although chromatin is the one universal and necessary constituent entering into the composition of the cell-nucleus, a simple mass of chromatin is not a nucleus. A true nucleus is a cell-organ, of greater or less structural complexity, which has been elaborated progressively in the course of the evolution of the cell; it is as much an organ of the cell as the brain is an organ of the human body. As a definite cell-organ, it performs in the life and economy of the cell definite functions. As an organ of the cell, however, it has no homologue or analogue in the body of the multicellular animals or plants; there is no organ of the human body, taken as a whole, similar or comparable to the nucleus of the cell.

The foregoing brief consideration of the nucleus leads me now to discuss in more detail the nature and properties of the essential nuclear substance, the so-called chromatin. To define, or characterise adequately, this substance is a difficult task. The name chromatin is derived from the fact that this substance has a peculiar affinity for certain dyes or stains, so that when a cell is treated with the appropriate colouring reagents—with so-called nuclear stains—the chromatin in the nucleus stands out sharply, by reason of being coloured in a different manner from the rest of the cell. In consequence, the statement is frequently made, in a loose manner and without reflection, that chromatin is recognised by its staining reactions, but in reality this is far from being true. When a preparation of an ordinary cell is made by the methods of technique commonly in use, the chromatin is recognised and identified by its position in a definite body with characteristic structure and relations to the cell as a whole, namely, the nucleus, and this is equally true whether the chromatin has been stained or not. Any so-called chromatin-stain colours many bodies which may occur in a cell besides the chromatin, and it may be necessary to try a great many different stains before a combination is found which will differentiate a given cytoplasmic enclosure from a true chromatin-grain by its colour-reactions. The so-called volutin-grains, for example, which are found commonly in the cytoplasm of many protists, are identified by the fact that they have a stronger affinity for "chromatin-stains" than chromatin itself.

What, then, is the true criterion of the chromatin-substance of living organisms? From the chemical point of view the essential substance of the cell-nucleus would appear to be characterised by a complexity of molecular structure far exceeding that of any other proteins, as well as by certain definite peculiarities. Especially characteristic of chromatin is its richness in phosphorus-compounds, and it stands apart also from other cell-elements in its solvent reactions, for example, resistance to peptic digestion. How far these features are common, however, to all samples of chromatin in all types of living organisms universally, cannot, I think, be stated definitely at present; at any rate, it is not feasible for a cytologist of these days to identify a granule in a living organism or cell as chromatin solely by its chemical reactions, although it is quite possible that at some future time purely chemical tests will be decisive upon this point—a consummation devoutly to be wished.

The only criterion of chromatin that is convincing to the present-day biologist is the test of its behaviour, that is to say, its relations to the life, activity, and development of the organism. I may best express my meaning by an objective example. If I make a preparation of *Arcella vulgaris* by suitable methods, I see the two conspicuous nuclei and also a ring of granules lying in the cytoplasm, stained in the same manner as the chromatin of the nuclei. Are these extranuclear granules to be regarded also as chromatin? Yes, most decidedly, because many laborious and detailed investigations have shown that from this ring of granules in Arcella nuclei can arise, usually termed "secondary" nuclei for no other reason than that they arise *de novo* from the extranuclear chromatin and quite independently of the "primary" nuclei. The secondary nuclei are, however, true nuclei in every respect, as shown by their structure, behaviour, and relations to the life-history of the organism; they may fuse as nuclei of gametes (pronuclei) in the sexual act, and they become, with or without such fusion, the primary nuclei of future generations of Arcella; they then divide by karyokinesis, when the organism reproduces itself in the ordinary way by fission, and are replaced in their turn by new secondary nuclei at certain crises in the life-history. In view of these facts, it can be asserted without hesitation that the ring of staining granules in Arcella is composed of, or at least contains, true chromatin-grains, extranuclear chromatin for which R. Hertwig's term chromidia is now used universally.

Having now defined or explained, as well as I am able, the terms of which I am about to make use, I return to my main theme, the cell and its evolution. To summarise the points already discussed, a typical cell is a mass of protoplasm differentiated into two principal parts or regions, the cytoplasm and the nucleus, or, it may be, two or more nuclei. The cytoplasm may or may not contain chromatin-grains in addition to other enclosures, and may possess cell-organs of various kinds. The nucleus, highly variable in minute structure, possesses one invariable constituent, the chromatin-material in the form of grains and masses of various sizes.

The cell, therefore, in its complete and typical form, is an organism of very considerable complexity of structure and multiplicity of parts. The truth of this proposition is sufficiently obvious even from simple inspection of the structural details revealed by the microscope in cells in the so-called "resting condition," but still more so from a study of their activities and functions. The vital processes exhibited by the cell indicate a complexity of organisation and a minuteness in the details of its mechanism which transcend our comprehension and baffle the human imagination, to the same extent as do the immensities of the stellar universe. If such language seems hyperbolic, it is but necessary to reflect on some of the established discoveries of cytology, such as the extraordinary degree of complication attained in the process of division of the nucleus by karyokinesis, or the bewildering series of events that take place in the nuclei of germ-cells in the processes of maturation and fertilisation. Such examples of cell-activity give us, as it were, a glimpse into the workshop of life and teach us that the subtlety and intricacy of the cell-microcosm can scarcely be exaggerated.

On the assumption that an organism so complex and potent was not created suddenly, perfect and complete as it stands, but arose, like all other organisms, by progressive evolution and elaboration of some simpler form and type of structure, it is legitimate to inquire which of the various parts of the cell are the older and more primitive and which are more recent acquisitions in the course of evolution. The evolution of the cell may be discussed as a morphological problem of the same order as that of the phylogeny of any other class or phylum of living beings, and by the same methods of inquiry.

The problem of cell-evolution may be attacked, beginning with the consideration of the primary structural differentiation of the typical cell, the distinction of nucleus, or rather chromatin, and cytoplasm.

Since no concrete foundation can be found for the view that cytoplasm and chromatin have a common origin in the evolution of living things, we are brought back to the view that one of them must have preceded the other in phylogeny.

For my part, I am unable to accept any theory of the evolution of the earliest forms of living beings which assumes the existence of forms of life composed entirely of cytoplasm without chromatin. All the results of modern investigations into the structure, physiology, and behaviour of cells, on the one hand, and of the various types of organisms grouped under the Protista, on the other hand—the combined results, that is to say, of cytology and protistology—appear to me to indicate that the chromatin-elements represent the primary and original living units or individuals, and that the cytoplasm represents a secondary product. I will summarise briefly the grounds that have led me to this conviction, and will attempt to justify the faith that I hold; but first I wish to discuss briefly certain preliminary considerations which seem to me of great importance in this connection.

It is common amongst biologists to speak of "living substance," this phrase being preceded by either the definite or the indefinite article—by either "the" or "a." If we pause to consider the meaning of the phrase, it is to be presumed that those who make use of it employ the term "substance" in the usual sense to denote a form of matter to which some specific chemical significance can be attached, which could conceivably be defined more or less strictly by a chemist, perhaps even reduced to a chemical formula of some type. But the addition of the adjective "living" negatives any such interpretation of the term "substance," since it is the fundamental and essential property of any living being that the material of which it is composed is in a state of continual molecular change and that its component substance or substances are inconstant in molecular constitution from moment to moment. When the body of a living organism has passed into a state of fixity of substance, it has ceased, temporarily or permanently, to behave as a living body; its fires are banked or extinguished. The phrase "living substance" savours, therefore, of a *contradictio in adjecto*; if it is "living" it cannot be a "substance," and if it is a "substance" it cannot be "living."

As a matter of fact, the biologist, when dealing with purely biological problems, knows nothing of a living substance or substances; he is confronted solely by living individuals, which constitute his primary conceptions, and the terms "life" and "living substance" are pure abstractions. Every living being presents itself to us as a sharply limited individual, distinct from other individuals and constituting what may be termed briefly a microcosmic unit, inasmuch as it is a unity which is far from being uniform in substance or homogeneous in composition, but which, on the contrary, is characterised by being made up of an almost infinite multiplicity of heterogeneous and mutually interacting parts. We recognise further that these living individuals possess invariably specific characteristics; two given living individuals may be so much alike that we regard them as of the same kind or "species," or they may differ so sharply that we are forced to distinguish between them specifically. Living beings are as much characterised by this peculiarity of specific individuality as by any other property or faculty which can be stated to be an attribute of life in general, and this is true equally of the simplest or the most complex organisms; at least we know of no form of life, however simple or minute, in which the combined features of individuality and specificity are not exhibited to the fullest extent.

The essential and distinctive characteristic of a living body of any kind whatsoever is that it exhibits while it lives permanence and continuity of individuality or personality, as manifested in specific behaviour, combined with incessant change and lability of substance; and further, that in reproducing its kind, it transmits its specific characteristics, with, however, that tendency to variability which permits of progressive adaptation and gradual evolutionary change. It is the distinctively vital property of specific individuality combined with "stuff-change" (if I may be allowed to paraphrase a Teutonic idiom) which marks the dividing line between biochemistry and biology. The former science deals with substances which can be separated from living bodies, and for the chemist specific properties are associated with fixity of substance; but the material with which the biologist is occupied consists of innumerable living unit-individuals exhibiting specific characteristics without fixity of substance. There is no reason to suppose that the properties of a given chemical substance vary in the slightest degree in space or time; but variability and adaptability are characteristic features of all living beings. The biochemist renders inestimable services in elucidating the physico-chemical mechanisms of living organisms; but the problem of individuality and specific behaviour, as manifested by living things, is beyond the scope of his science, at least at present. Such problems are essentially of distinctively vital nature, and their treatment cannot be brought satisfactorily into relation at the present time with the physico-chemical interactions of the substances composing the living body. It may be that this is but a temporary limitation of human knowledge prevailing in a certain historical epoch, and that in the future the chemist will be able to correlate the individuality of living beings with their chemico-physical properties, and so explain to us how living beings first came into existence; how, that is to say, a combination of chemical substances, each owing its characteristic properties to a definite molecular composition, can produce a living individual in which specific peculiarities are associated with matter in a state of flux. But it is altogether outside the scope and aim of this address to discuss whether the boundary between biochemistry and biology can be bridged over, and if so, in what way. I merely wish to emphasise strongly that if a biologist wishes to deal with a purely biological problem, such as evolution or heredity, for example, in a concrete and objective manner, he must do so in terms of living specific individual units. It is for that reason that I shall speak, not of the chromatin-substance, but of chromatinic elements, particles or units, and I hope that I shall make clear the importance of this distinction.

To return now to our chromatin; I regard the chromatinic elements as being those constituents which are of primary importance in the life and evolution of living organisms mainly for the following reasons: the experimental evidence of the preponderating physiological *rôle* played by the nucleus in the life of the cell; the extraordinary individualisation of the chromatin-particles seen universally in living organisms, and manifested to a degree which raises the chromatinic units to the rank of living individuals exhibiting specific behaviour, rather than that of mere substances responsible for certain chemico-physical reactions in the life of the organism; and last, but by no means least, the permanence and, if I may use the term, the immortality of the chromatinic particles in the life-cycle of organisms generally. I will now deal with these points in order.

The results obtained by physiological experiments with regard to the functions of the nuclear and cytoplasmic constituents of the cell are now well known and are cited in all the text-books. It is not necessary, therefore, that I should discuss them in detail. I content myself with quoting a competent and impartial summary of the results obtained:—

"A fragment of a cell deprived of its nucleus may live for a considerable time and manifest the power of co-ordinated movements without perceptible impairment. Such a mass of protoplasm is, however, devoid of the powers of assimilation, growth, and repair, and sooner or later dies. In other words, those functions that involve destructive metabolism may continue for a time in the absence of the nucleus; those that involve constructive metabolism cease with its removal. There is, therefore, strong reason to believe that the nucleus plays an essential part in the constructive metabolism of the cell, and through this is especially concerned with the formative processes involved in growth and development. For these and many other reasons . . . the nucleus is generally regarded as a controlling centre of cell-activity, and hence a primary factor in growth, development, and the transmission of specific qualities from cell to cell, and so from one generation to another.[2]

I have mentioned already in my introductory remarks that the only trustworthy test of chromatin is its behaviour, and the whole of modern cytological investigation bears witness to the fact that the chromatinic particles exhibit the characteristic property of living things generally, namely, individualisation combined with specific behaviour. In every cell-generation in the bodies of ordinary animals and plants the chromatin-elements make their appearance in the form of a group of chromosomes, not only constant in number for each species, but often exhibiting such definite characteristics of size and form, that particular, individual chromosomes can be recognised and identified in each group throughout the whole life-cycle. Each chromosome is to be regarded as an aggregate composed of a series of minute chromatinic granules or chromioles, a point which I shall discuss further presently.

Even more remarkable than the relation of the chromosomes to cell-reproduction is their behaviour in relation to sexual phenomena. In the life-cycles of Metazoa the sexual act consists of the fusion of male and female pronuclei, each containing a definite and specific number of chromosomes, the same number usually, though not always, in each pronucleus. It has been established in many cases, and it is perhaps universally true, that in the act of fertilisation the male and female chromosomes remain perfectly distinct and separate in the synkaryon or nucleus formed by the union of the two pronuclei, and, moreover, that they continue to maintain and to propagate their distinct individuality in every subsequent cell-generation of the multicellular organism produced as a result of the sexual act. In this way, every cell of the body contains in its nucleus distinct chromatinic elements which are derived from both male and female parents and which maintain unimpaired their distinct and specific individuality through the entire life-cycle. This distinctness is apparent at least in the germ-cell-cycle of the organism, but may be obscured by secondary changes in the nuclei of the specialised tissue-cells.

Only in the very last stage of the life-cycle do the group of male and female chromosomes modify their behaviour in a most striking manner. In the final generation of oogonia or spermatogonia, from which arise the oocytes and spermatocytes which in their turn produce the gamete-cells, it is observed that the male and female chromosomes make a last appearance in their full number, and then fuse in pairs, so as to reduce the number of chromosomes to half that previously present.

As Vejdovsky has pointed out, there can be no more striking evidence of the specific individuality of the chromosomes than their fusion or copulation in relation to the sexual act. Is there any other constant element or constituent of living organisms exhibiting to anything like the same degree the essentially vital characteristics of individuality manifested in specific behaviour? If there is, it remains to be discovered.

I come now to the question of the permanence and immortality, in the biological sense of the word, of the chromatinic particles, which may be summarily stated as follows: the chromatinic particles are the only constituents of the cell which maintain persistently and uninterruptedly their existence throughout the whole life-cycle of living organisms universally.

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[2] E. B. Wilson, "The Cell," second edition, 1911, pp. 30, 31.

I hope I shall not be misunderstood when I enunciate this apparently sweeping and breathless generalisation. I am perfectly aware that in the life-cycle of any given species of organism there may be many cell-constituents besides the chromatin-particles that are propagated continuously through the whole life-cycle; but cell-elements which appear as constant parts of the organisation of the cell throughout the life-cycle in one type of organism may be wanting altogether in other types. With the exception of the chromatin-particles there is no cell-constituent that can be claimed to persist throughout the life-cycles of organisms universally. It may be that this is only the result of our incomplete knowledge at the present time. I am prepared, however, to challenge anyone to name or to discover any cell-constituent, other than the chromatinic particles, which are present throughout the life-cycle, not merely of some particular organism, but of organisms universally.

To recapitulate my argument in the briefest form; the chromatinic constituents of the cell contrast with all the other constituents in at least three points: physiological predominance, especially in constructive metabolism; specific individualisation; and permanence in the sense of potential biological immortality. Any of these three points, taken by itself, is sufficient to confer a peculiar distinction, to say the least, on the chromatin-bodies; but taken in combination they appear to me to furnish overwhelming evidence for regarding the chromatin-elements as the primary and essential constituents of living organisms, and as representing that part of a living body of any kind which can be followed by the imagination, in the reverse direction of the propagative series, back to the very starting-point of the evolution of living beings.

In the attempt to form an idea as to what the earliest type of living being was like, in the first place, and as to how the earliest steps in its evolution and differentiation came about, in the second place, we have to exercise the constructive faculty of the imagination guided by such few data as we possess. It is not to be expected, therefore, that agreement can be hoped for in such speculations; it would indeed be very undesirable, in the interests of science, that there should be no conflict of opinion in theories which, by their very nature, are beyond any possibility of direct verification at the present time. The views put forward by any man do but represent the visions conjured up by his imagination, based upon the slender foundation of his personal knowledge, more or less limited, or intuition, more or less fallacious, of an infinite world of natural phenomena. Consequently such views may be expected to diverge as widely as do temperaments. If, therefore, I venture upon such speculations, I do so with a sense of personal responsibility and as one wishing to stimulate discussion rather than to lay down dogma.

To me, therefore, the train of argument that I have set forth with regard to the nature of the chromatinic constituents of living organisms appears to lead to the conclusion that the earliest living beings were minute, possibly ultramicroscopic particles which were of the nature of chromatin. How far the application of the term chromatin to the hypothetical primordial form of life is justified from the point of view of substance, that is to say in a biochemical sense, must be left uncertain. In using the term chromatin I must be understood to do so in a strictly biological sense, meaning thereby that these earliest living things were biological units or individuals which were the ancestors, in a continuous propagative series, of the chromatinic grains and particles known to us at the present day as universally-occurring constituents of living organisms. Such a conception postulates no fixity of chemical nature; on the contrary, it implies that as substance the primitive chromatin was highly inconstant, infinitely variable, and capable of specific differentiation in many divergent directions.

For these hypothetical primitive organisms we may use Mereschkowsky's term biococci. They must have been free-living organisms capable of building up their living bodies by synthesis of simple chemical compounds. We have as yet no evidence of the existence of biococci at the present time as free-living organisms; the nearest approach to any such type of living being seems to be furnished by the organisms known collectively as Chlamydozoa, which up to the present have been found to occur only as pathogenic parasites. In view, however, of the minuteness and invisibility of these organisms, it is clear that they could attract attention only by the effects they produce in their environments. Consequently the human mind is most likely to become aware in the first instance of those forms which are the cause of disturbance in the human body. If free-living forms of biococci exist, as is very possible and even probable, it is evident that very delicate and accurate methods of investigation would be required to detect their presence.

If it be permissible to draw conclusions with regard to the nature of the hypothetical biococci from the somewhat dubious, but concrete, data furnished by the Chlamydozoa, the following tentative statements may be postulated concerning them. They were (or are) minute organisms, each a speck or globule of a substance similar in its reactions to chromatin. Their substance could be described as homogeneous with greater approach to accuracy than in the case of any other living organism, but it is clear that no living body that is carrying on constructive and destructive metabolism could remain for a moment perfectly homogeneous or constant in chemical composition. Their bodies were not limited by a rigid envelope or capsule. Reproduction was effected by binary fission, the body dividing into two with a dumbbell-shaped figure. Their mode of life was vegetative—that is to say, they reacted upon their environmental medium by means of ferments secreted by their own body-substance. The earliest forms must have possessed the power of building up their protein-molecules from the simplest inorganic compounds; but different types of biococci, characterised each by specific reactions and idiosyncrasies, must have become differentiated very rapidly in the process of evolution and adaptation to divergent conditions of life.

Consideration of the existing types and forms of living organisms shows that from the primitive biococcal type the evolution of living things must have diverged in at least two principal directions. Two new types of organisms arose, one of which continued to specialise further in the vegetative mode of life, in all its innumerable variations, characteristic of the biococci, while the other type developed an entirely new habit of life—namely, a predatory existence. I will consider these two types separately.

(1) In the vegetative type the first step was that the body became surrounded by a rigid envelope. Thus came into existence the bacterial type of organism, the simplest form of which would be a Micrococcus, a minute globule of chromatin surrounded by a firm envelope. From this familiar type an infinity of forms arise by processes of divergent evolution and adaptation. I will not attempt, however, to follow up the evolution of the bacterial type further, or to discuss what other types of living organisms may be affiliated with it, as I have no claims to an expert knowledge of these organisms.

(2) In the evolution from the biococcus of the pre-

datory type of organism, the data at our disposal appear to me to indicate very clearly the nature of the changes that took place, as well as the final result of these changes, but leave us in the dark with regard to some of the actual details of the process. The chief event was the formation, round the biococci, of an enveloping matrix of protoplasm for which the term periplasm (Lankester) is most suitable. The periplasm was an extension of the living substance which was distinct in its constitution and properties from the original chromatinic substance of the biococcus. The newly formed matrix was probably from the first a semi-fluid substance of alveolar structure and possessed two important capabilities as the result of its physical structure; it could perform streaming movements of various kinds, more especially amœboid movement; and it was able to form vacuoles internally. The final result of these changes was a new type of organism which, compared with the original biococci, was of considerable size, and consisted of a droplet of alveolar, amœboid periplasm in which were imbedded a number of biococci. Whether this periplasm made its first appearance around single individual biococci, or whether it was from the first associated with the formation of zooglœa-like colonies of biococci, must be left an open question.

Thus arose in the beginning the brand of Cain, the prototype of the animal—that is to say, a class of organism which was no longer able to build up its substance from inorganic materials in the former peaceful manner, but which nourished itself by capturing, devouring, and digesting other living organisms. The streaming movements of the periplasm enabled it to flow round and engulph other creatures; the vacuole-formation in the periplasm enabled it to digest and absorb the substance of its prey by the help of ferments secreted by the biococci. By means of these ferments the ingested organisms were killed and utilised as food, their substance being first broken down into simpler chemical constituents and then built up again into the protein-substances composing the body of the captor.

A stage of evolution is now reached which I propose to call the pseudo-moneral or cytodal stage, since the place of these organisms in the general evolution of life corresponds very nearly to Haeckel's conception of the Monera as a stage in the evolution of organisms, though not at all to his notions with regard to their composition and structure. The bodies of these organisms did not consist of a homogeneous albuminous "plasson," but of a periplasm corresponding to the cytoplasm of the cell, containing a number of biococci or chromatin-grains. In the life-cycles of Protozoa, especially of Rhizopods, it is not at all infrequent to find developmental phases which reproduce exactly the picture of the pseudo-moneral stage of evolution, phases in which the nucleus or nuclei have disappeared, having broken up into a number of chromatin-grains or chromidia scattered through the cytoplasm.

The next stage in evolution was the organisation of the chromatin-grains (biococci) into a definite cell-nucleus. This is a process which can be observed actually taking place in many Protozoa in which "secondary" nuclei arise from chromidia. With the formation of the nucleus the cytode or pseudo-moneral stage has become a true cell of the simplest type, for which I propose the term *protocyte*. It is now the starting-point of an infinite series of further complications and elaborations in many directions. With all the diverse modifications of the cell the nucleus remains comparatively uniform. It may, indeed, vary infinitely in details of structure, but in principle it remains a concentration or aggregation of numerous grains of chromatin supported on some sort of framework over which the grains are scattered or clumped in various ways, supplemented usually by plastin or nucleolar substance either as a cementing ground-substance or as discrete grains, and the whole marked off sharply from the surrounding cytoplasm, with or without a definite limiting membrane. There is, however, one point in which the nucleus exhibits a progressive evolution of the most important kind. I refer to the gradual elaboration and perfection of the reproductive mechanism, the process whereby, when the cell reproduces itself by fission, the chromatin-elements are distributed between the two daughter-cells.

The chromatin-constituents of the cell are regarded, on the view maintained here, as a number of minute granules, each representing a primitive independent living individual or biococcus. To each such granule must be attributed the fundamental properties of living organisms in general; in the first place metabolism, expressed in continual molecular change, in assimilation and in growth, with consequent reproduction; in the second place specific individuality. As the result of the first of these properties the chromatin-granules, often perhaps ultra-microscopic, may be larger or smaller at different times, and they multiply by dividing each into two daughter-granules. As a result of the second property, chromatin-granules in one and the same cell may exhibit qualitative differences and may diverge widely from one another in their reactions and effects on the vital activities of the cell. The chromatin-granules may be either in the form of scattered chromidia or lodged in a definite nucleus. When in the former condition, I have proposed the term chromidiosome for the ultimate chromatinic individual unit; on the other hand, the term chromiole is commonly in use for the minute chromatin-grains of the nucleus.

In the phase of evolution that I have termed the pseudomoneral or cytodal phase, in which the organism was a droplet of periplasm containing scattered biococci or chromidiosomes, metabolism would result in an increase in the size of the cytode-body as a whole, accompanied by multiplication of the chromidiosomes. Individualisation of the cytodes would tend to the acquisition of a specific size—that is to say, to a limitation of the growth—with the result that when certain maximum dimensions were attained the whole cytode would divide into two or more smaller masses amongst which the chromidiosomes would be partitioned.

In the next stage of evolution, the protocyte with a definite nucleus, it is highly probable that at each division of the cell-body, whether into two or more parts, the primitive method of division of the nucleus was that which I have termed elsewhere "chromidial fragmentation"; that is to say, the nucleus broke up and became resolved into a clump of chromidiosomes, which separated into daughter-clumps from which the daughter-nuclei were reconstituted. Instances of nuclear divisions by chromidial fragmentation are of common occurrence among the Protozoa, and represent probably the most primitive and direct mode of nuclear division.

It is clear, however, that if the chromatin-grains are to be credited with specific individuality and qualitative differences amongst themselves, this method of nuclear division presents grave imperfections and disadvantages, since even the quantitative partition of the chromatin is inexact, while the qualitative partition is entirely fortuitous.

It is not surprising, therefore, to find that the process of nuclear division undergoes a progressive elaboration of mechanism which has the result of ensuring that the twin sister-granules of chromatin produced by division of a single granule shall be distributed between the two daughter-cells, so that for every chromatin-grain obtained by one daughter-cell an exact counterpart is obtained by the other; in other words, of ensuring an exact qualitative, as well as quantitative, partition of the chromatin-particles. In its perfect form this type of nuclear division is known as karyokinesis or mitosis, and all stages in its progressive development are to be found in the Protozoa.

In the evolution of nuclear division by karyokinesis two distinct processes are being developed and perfected in a parallel manner, but more or less independently; first, the method of the partition and distribution of the chromatin-grains between the two daughter-nuclei; secondly, the mechanism whereby the actual division of the nucleus and the separation of the two daughter-nuclei are effected in the cell-division. I have dealt elsewhere with the evolution of the mechanism of karyokinesis as exemplified by the numerous and varied types of the process found amongst the Protozoa, and I need not discuss the matter further here, but the behaviour of the chromatin-grains may be dealt with briefly. The main feature in the process of the exact quantitative and qualitative distribution of the daughter-chromatin between the daughter-nuclei is the aggregation of the chromatin-grains or chromioles into definite, highly individualised structures known as chromosomes. In the most perfected forms of the process of chromosome-formation the chromioles become united into a linear series termed by Vejdovsky a chromoneme, which is supported upon a non-chromatinic basis or axis.

The actual division of the chromatin takes place by the longitudinal splitting of the chromoneme—in other words, by simultaneous division into two of each of the chromioles of which the thread is composed. In this way every chromiole which was contained in the original chromoneme is represented by a daughter-chromiole in each of the two daughter-chromonemes. It follows that the familiar process of the splitting of the chromosomes in karyokinesis is a mechanism which brings about in the most simple, sure and direct manner an exact quantitative and qualitative partition of the chromatin-grains between the two daughter-nuclei.

The chromatin-cycle of a cell in which the process of division by karyokinesis takes place in its most perfectly developed form, may, therefore, be conceived as follows. The nucleus in its resting state contains a definite number of companies or brigades of chromatinic units (chromioles), each brigade spread over a certain extent of the nuclear framework forming a karyomere. As a preparation to division each separate brigade of chromioles falls into line as the chromoneme, forming with its supporting substance the chromosome; there are formed, therefore, just so many chromosomes as there were karyomeres in the nucleus. In this disciplined and orderly array each chromiole undergoes its division into two daughter-chromioles, so that each file or chromoneme of chromioles splits into two files. At the reconstitution of the daughter-nuclei each daughter-chromosome gives rise to a karyomere again, the chromioles falling out of the ranks and disposing themselves in an apparently irregular manner on the newly built framework of the daughter-nucleus to constitute their own particular karyomere. Thus karyokinesis differs only from the most primitive method of division by chromidial fragmentation in that what was originally a haphazard method of distribution has become a disciplined and orderly manœuvre, performed with the precision of the parade-ground, but in a space far less than that of a nutshell.

In the nuclear division of Protozoa, without going into detail, it may be stated broadly that all stages are to be found of the gradual evolution of the tactical problem which constitutes karyokinesis.

I have dealt briefly with the problem of the evolution of karyokinesis because the process of nuclear division is, in my opinion, of enormous importance in the general evolution of living organisms. I have expressed elsewhere the opinion that the very existence of multicellular organisms composed of definite tissues is impossible until the process of karyokinesis has been established and perfected. For tissue-formation it is essential that all the cells which build up any given tissue should be similar, practically to the point of identity, in their qualities; and if it is the chromatin-elements of the cell which determine its qualities and behaviour, then the exact qualitative division of the chromatin, as effected in karyokinesis, is indispensable as a preliminary to the production of identically similar daughter-cells by division of a parent-cell. Hence it becomes intelligible why, amongst Metazoa, we find the occurrence of nuclear division by karyokinesis in its most perfect form to be the rule, and "direct" division of the nucleus to be the rare exception, while, on the other hand, in the Protista, and especially in the Protozoa, we find every possible stage in the gradual evolution of the exact partition of the chromatin in the process of nuclear division, from chromidial fragmentation or the most typical amitosis up to processes of karyokinesis as perfect as those of the Metazoa.

I have confined myself to the evolution of the cell as this organism is seen in its typical form in the bodies of the multicellular organisms, starting from the simplest conceivable type of living being, so far as present knowledge enables us to conceive it. But there is not the slightest reason to suppose that the evolution of the Protista took place only in the direction of the typical cell of the cytologist. Besides the main current leading up to the typical cell, there were certainly other currents tending in other directions and leading to types of structure very unlike the cells composing the bodies of multicellular organisms.

In this address I have set forth my conceptions of the nature of the simplest forms of life and of the course taken by the earliest stages of evolution, striving all through to treat the problem from a strictly objective point of view, and avoiding as far as possible the purely speculative and metaphysical questions which beset like pitfalls the path of those who attack the problem of life and vitalism. I have, therefore, refrained as far as possible from discussing such indefinable abstractions as "living substance" or "life," phrases to which no clear meaning can be attached.

How far my personal ideas may correspond to objective truth I could not, of course, pretend to judge. If I might be permitted to attempt an impartial criticism of my own scheme, I think it might be claimed that the various forms and types of organisms in my evolutionary series, namely, the simple cell or protocyte, the cytode or pseudomoneral stage, the micrococcus, even the biococcus, are founded on concrete evidence, and can be regarded as types actually existent in the present or past. On the other hand, the *rôle* assigned by me to each type in the pageant of evolution is naturally open to dispute. For example, I agree with those who derive the bacteria as primitive, truly non-cellular organisms, directly from the biococcus through an ancestral form, and not at all with those who would regard the bacteria as degenerate or highly specialised cells. But the crux of my scheme is the homology postulated between the biococcus and the chromatinic particle

—chromidiosome or chromiole—of true cells. In support of this view, of which I am not the originator, I have set forth the reasons which have convinced me that the extraordinary powers and activities exhibited by the chromatin in ordinary cells are such as can only be explained on the hypothesis that the ultimate chromatinic units are to be regarded as independent living beings, as much so as the cells composing the bodies of multicellular organisms; and, so far as I am concerned, I must leave the matter to the judgment of my fellow-biologists.

I may point out, in conclusion, that general discussions of this kind may be useful in other ways than as attempts to discover truth or as a striving towards a verity which is indefinable and perhaps unattainable. Even if my scheme of evolution be but a midsummer night's fantasy, I claim for it that it co-ordinates a number of isolated and scattered phenomena into an orderly and, I think, intelligible sequence, and exhibits them in a relationship which at least enables the mind to obtain a perspective and comprehensive view of them. Rival theories will be more, or less, useful than mine, according as they succeed in correlating more, or fewer, of the accumulated data of experience. If in this address I succeed in arousing interest and reflection, and in stimulating inquiry and controversy, it will have fulfilled its purpose.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

BIRMINGHAM.—A portrait of Prof. Lapworth (by Mr. B. Munns) has been presented to the University by Mr. W. Waters Butler.

Dr. Elgood Turner has been appointed demonstrator in anatomy for women students in succession to Dr. Violet Coghill, who has resigned.

Dr. Mary Clarke has been appointed lecturer in hygiene to the students of the Training College for Women.

Mr. B. Lloyd has been appointed demonstrator in anatomy for the session.

GLASGOW.—Prof. John Ferguson has resigned the Regius chair of chemistry, to which he was appointed in 1874. He had previously for nine and a half years been a junior teacher in the department. He has therefore been a member of the staff for more than fifty years. During his tenure of office the chemical laboratories of the University have been greatly enlarged, and separate departments of organic chemistry, metallurgical chemistry, and physical chemistry have been instituted under the charge of special lecturers. Among Prof. Ferguson's former pupils are many distinguished chemists, including Prof. Millar Thomson, Sir William Ramsay, Sir J. J. Dobbie, Carrick Anderson, Profs. Henderson, Boyd, Long, and Parker, and Dr. A. W. Stewart.

LEEDS.—The Vice-Chancellor has received the following message from the King:—"His Majesty feels that the assistance of the universities is a great asset to the cause for which we are fighting, as science plays such a prominent part in modern warfare."

LONDON.—A course in dynamical meteorology with practical work will be given at the Meteorological Office, South Kensington, on Fridays, at 3 p.m., during the second term by Sir Napier Shaw, director of the Meteorological Office and University reader in meteorology. The fortnightly meetings at the Meteorological Office for discussion of important contributions to current meteorology in colonial or foreign journals will be resumed at 5 p.m. on Monday, October 25, and will be continued on alternate Mondays until March 27, 1916, with the exception of December 20th and January 3. Students wishing to attend should communicate with the reader at the Meteorological Office. The lectures are addressed to advanced students of the University and to others interested in the subject. Admission free, by ticket, to be obtained on application at the Meteorological Office.

A COPY of the September issue of the *Reading University College Review* has been received. It contains a revised list of the names of present members of the staff, past and present students, and present servants of the college who are serving with his Majesty's Forces, or in the French Army. The college may well be proud of its roll of honour. Mr. W. E. G. Atkinson, who was formerly a lecturer of the Department of Agriculture, has been killed in action in the Dardanelles, and Mr. T. G. Malpas, demonstrator in the physics laboratory, has been wounded. The review also contains a list of recent original contributions to science by members of the staff.

THE various courses of instruction to be given at the North of Scotland College of Agriculture during the present session are set out in detail in the current calendar of the college. The courses are designed to prepare students for the degree of B.Sc. in agriculture in the University of Aberdeen, the university diploma in agriculture, the national diplomas in agriculture and dairying, the degree of B.Sc. in forestry, and the certificate in forestry granted by the Highland and Agricultural Society of Scotland. All courses are open to women as well as to men. With the aid of a grant from the Development Commission, a research department has been instituted. In accordance with the conditions under which the grant is received from the Commission, this department is managed by a joint committee representing the governors and the University Court. We notice the governors have acquired a college farm. Experiments and demonstrations will be carried out. Experimental plots, an experimental and demonstration garden, and a horticultural department, are in course of construction. It is also intended to carry on feeding and other experiments upon stock. The farm is conveniently situated about five miles from Aberdeen. It is proposed to institute a school of rural domestic economy for girls. There is a large mansion house on the college farm estate which will be equipped as a residence for the girls attending the school, and in which classes will be carried on.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, October 4.—M. Ed. Perrier in the chair.—J. **Boussinesq**: The correct calculation of the influence of climatic inequality on the velocity of increase of terrestrial temperatures with depth from the surface.—H. **Douvillé**: The orbitoids of the peninsula of California. A study of material arising from the geological explorations of Arnold Heim. Some specimens belong to the genus Orthophragmina, and it is the first time these have been discovered in this region. Some rare Foraminifera include specimens of *Amphistegina Niasi*.—E. E. **Barnard**: Some supposed movements in stars near the cluster Messier 11 = N.G.C. 6705. The observation of J. Comas Solá on movements of stars in the neighbourhood of this cluster do not appear to be well founded. They were based on the stereoscopic examination of photographs taken at an interval of three years. The author has examined photographs of the same